Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at http://about.jstor.org/participate-jstor/individuals/early-journal-content.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

BRIEFER ARTICLES

NOTES ON THE EMBRYOLOGY OF THE NYMPHAEACEAE

(WITH PLATE VI)

Within the past few years the embryology of the Nymphaeaceae has attracted considerable attention, beginning with LYON'S studies on Nelumbo,[1] followed by my own paper on *Castalia odorata* and *Nymphaea advena*[2] and by CONARD'S[3] monograph on the water lilies. The differences of opinion as to certain characters of the embryo, expressed by CONARD on the one side and LYON and myself on the other, led me to believe that the embryological characters are subject to considerable variation, or that some serious error had been made. However, I determined to verify my work on *Castalia odorata* and *Nymphaea advena*, if possible, and YORK'S[4] work on Nelumbo. Recently SEATON[5] has published a paper on *Nymphaea advena*, which also deserves consideration in this review of the subject.

My recent studies have been confined to the disputed points in *Castalia odorata*, *Nymphaea advena*, and *Nelumbo lutea*, and therefore other species and other questions have been given very little or no consideration.

EMBRYO SAC

The mature embryo sac is subject to considerable variation. However, I am now convinced that the formation of a cross-wall between the two daughter nuclei, which are formed by the first division of the endosperm nucleus, is a constant character, although SEATON failed to find it in *Nymphaea advena*. It is usually very delicate and is no doubt frequently destroyed in the preparation of the material. The writer has observed it repeatedly in *Castalia odorata* and in *Nymphaea advena*, where it can be seen without great difficulty; also in *Cabomba piauhiensis* and in *Brasenia purpurea*, where it is very difficult to demonstrate. YORK noted it in *Nelumbo lutea*, but according to his observations one of these two cells again divides, thus forming three superposed cells, each of which is active in the formation of the endosperm. However, he did not observe the formation of the large vesicular cell, which is so characteristic of the other genera of this family. My recent studies, which will be referred to later in this paper, do not fully agree with those of YORK in regard to the vesicular cell.

---

[1] LYON, H. L., Preliminary note on the embryogeny of Nelumbo. Science N. S. **13**:470. 1900.

———, Observations on the embryogeny of Nelumbo. Minn. Bot. Stud. **2**:643–655. 1901.

[2] COOK, M. T., Development of the embryo sac and embryos of *Castalia odorata* and *Nymphaea advena*. Bull. Torr. Bot. Club **29**:211–220. 1902.

[3] CONARD, H. S., The water lilies: a monograph of the genus Nymphaea. Carnegie Inst. Wash. Publ. 4. 1905.

COOK, M. T., The embryology of some Cuban Nymphaeaceae. BOT. GAZETTE **42**:376–392. 1906.

[4] YORK, H. H., The embryo sac and embryo of Nelumbo. Ohio Nat. **4**:167–176. 1904.

[5] SEATON, SARA, The development of the embryo-sac of *Nymphaea advena*. Bull. Torr. Bot. Club **35**:283–290. 1908.

The daughter nucleus in the micropylar end of the sac always divides to form the endosperm. The formation of the nucellar tube, into which the other nucleus usually and possibly always passes, is subject to considerable variation in the different species. In the genus Nymphaea it is a cylindrical tube, which extends almost the entire length of the ovule (*fig. 1*). In Castalia it may be in the form of a tube which is practically the same as in Nymphaea, but it is usually somewhat shorter and narrower. In some of my recent studies I have found individuals in which there were well-formed tubes extending only about one-half the length of the ovule (*fig. 2*), while in other individuals it extended not more than one-third the length of the ovule and tapered to a point (*fig. 3*). In *Castalia ampla*, as previously reported by me, it develops into a short, sac-like structure (*fig. 4*), which is eventually overgrown by the micropylar part of the sac (*fig. 5*). In *Brasenia purpurea* and *Cabomba piauhiensis*, the tube is very long, extending almost the entire length of the ovule, and very small (*fig. 6*). In *Nelumbo lutea*, according to these studies, the tube is very irregular in form and extends about two-thirds the length of the ovule (*fig. 7*).

In these recent studies one individual of *Nelumbo lutea* was observed in which two sacs were formed one below the other in the main axis of the ovule (*fig. 8*). The antipodal ends were in contact, and the sac next to the micropyle was about four times as large as the other. It showed a fully developed egg-apparatus, and the two polar nuclei were in contact, but the antipodals had disintegrated. The small sac which was farthest from the micropyle showed the egg, one synergid, the three antipodals, and was filled with the characteristic endosperm. In the antipodal end of the sac was a small, deeply colored mass, which was possibly the remains of the disintegrating tube nucleus (*fig. 8 t*). This extra sac was evidently derived from one of the sister megaspores. YORK observed many cases in which extra, imperfect sacs were produced, and expressed the opinion that they were from sister megaspores rather than from independent megasporocytes. I have previously recorded the occurrence of extra, imperfect sacs in Castalia, Brasenia, and Cabomba, but in all cases I considered them to have been derived from independent archesporial cells. In this new case, to which I now refer, it was evident that the second sac had not been penetrated by a pollen tube, and of course the endosperm had been formed without triple fusion. In this connection I wish to say that I have previously observed sacs of species of this family which were filled with typical endosperm, but without embryos, and in which it appeared that there had been no fertilization.

However, in the normal embryo sacs of *Nelumbo lutea*, the polar nuclei united in the usual manner and then divided to form the endosperm. I was unable to follow the early divisions of the endosperm, but in a few instances I found a well-marked cell wall across the sac, which I take to be the wall that is usually formed between the two daughter nuclei after the first division of the endosperm (*fig. 10*). The tube nucleus (*t*) was comparatively small and undergoing disintegration. The antipodal end of the sac is in contact with an axial mass of cells (*fig. 11*), which may consist of a single row of cells or many rows. These cells are rich in protoplasm and eventually disintegrate, probably forming food for the developing embryo. They have been referred to by YORK, who gave a discussion of their appearance and behavior, and figured them in his paper. They are very similar to the cells in the secondary sac (*fig. 8*), and I am inclined to consider them as the vestiges of undeveloped embryo sacs. Near the cross-wall, but in the micropylar chamber of the sac shown in *fig. 10*, was a rather compact mass of cells (*d*), which somewhat resembles a second embryo, but a careful examination leads me to believe it a part of the endosperm.

In one ovule of *Castalia odorata* the embryo was well advanced, although the endosperm nucleus had remained undivided (*fig. 13*).

EMBRYOS

In my first paper I stated that the embryos are without suspensor, except in the case of *Nymphaea advena*, in which a latent suspensor is developed. CONARD afterward described and figured a suspensor for Castalia. In a more recent paper on the Cuban forms, I described the embryo of *Nymphaea advena* as developing in the same manner as our northern form, except that the latent suspensor was more prominent in the Cuban form. However, the embryos of *Castalia ampla* and *C. pubescens* develop with filamentous suspensors in the manner described by CONARD for *Castalia odorata*, while Cabomba and Brasenia both develop with short filamentous suspensors. SEATON'S observations on the embryo of *Nymphaea advena* coincided with my first paper on this subject.

In these later studies I have found that the embryo of *Nymphaea advena* originated (*fig. 12*) and develops in the same manner as previously described by me, but that in some instances the latent suspensor is almost or quite as prominent as in the Cuban form. In *Castalia odorata* I found both types of embryos described by me in my first paper; i. e., without a suspensor (*fig. 13*), and also with a suspensor (*fig. 14*), as described by CONARD and by myself in my paper on the Cuban Nymphaeaceae. These recent studies on *Nelumbo lutea* showed in most cases a spherical embryo, without a suspensor, and agreed fully with the observations of LYON and YORK, but in one or two cases there appeared a small suspensor (*fig. 10*) of the same type as described for *Nymphaea advena*, except that it appeared somewhat earlier in the development of the embryo.

Recent studies on *Castalia odorata* and *Nymphaea advena* confirm the previous observations of myself and others on the formation of a cotyledonary ridge, from which the two cotyledonary lobes are developed.

The studies referred to in this paper convince me that the species of Nymphaeaceae are either very plastic and subject to considerable variation, or that we are confusing very closely related forms.

SUMMARY

1. Extra embryo sacs are frequently formed.
2. The cross-wall between the two daughter nuclei, which are formed by the first division of the endosperm nuleus, is usually present, although so delicate that it is very difficult to demonstrate.
3. The nucleus in the micropylar end of the sac forms the endosperm.
4. The nucellar tube is somewhat different in the different species, and also subject to great variation, especially within the genus Castalia.
5. The embryo of Nymphaea originates without a suspensor and later develops a latent suspensor; the embryo of Castalia originates either without or with a filamentous suspensor; the embryos of Cabomba and Brasenia with short filamentous suspensors; and the embryo of Nelumbo either with or without the very short latent suspensor.—MEL. T. COOK, *Delaware Agricultural Experiment Station, Newark, Delaware.*

EXPLANATION OF PLATE VI

Abbreviations: *e* embryo; *t* tube nucleus; *n* egg; *s* synergids: *a* antipodals; *w* cross-wall.

FIGS. 1–7.—Diagrams of ovules, showing sac and nucellar tube: *fig. 1*, *Nymphaea advena; figs. 2, 3, Castalia odorata; figs. 4, 5, Castalia ampla; fig. 6*, Brasenia and Cabomba; *fig. 7, Nelumbo lutea.*

FIG. 8.—Two embryo sacs in axillary order; the one next to the micropyle is the larger.

FIG. 9.—Embryo sac of *Nelumbo lutea*, showing egg apparatus and endosperm nucleus.

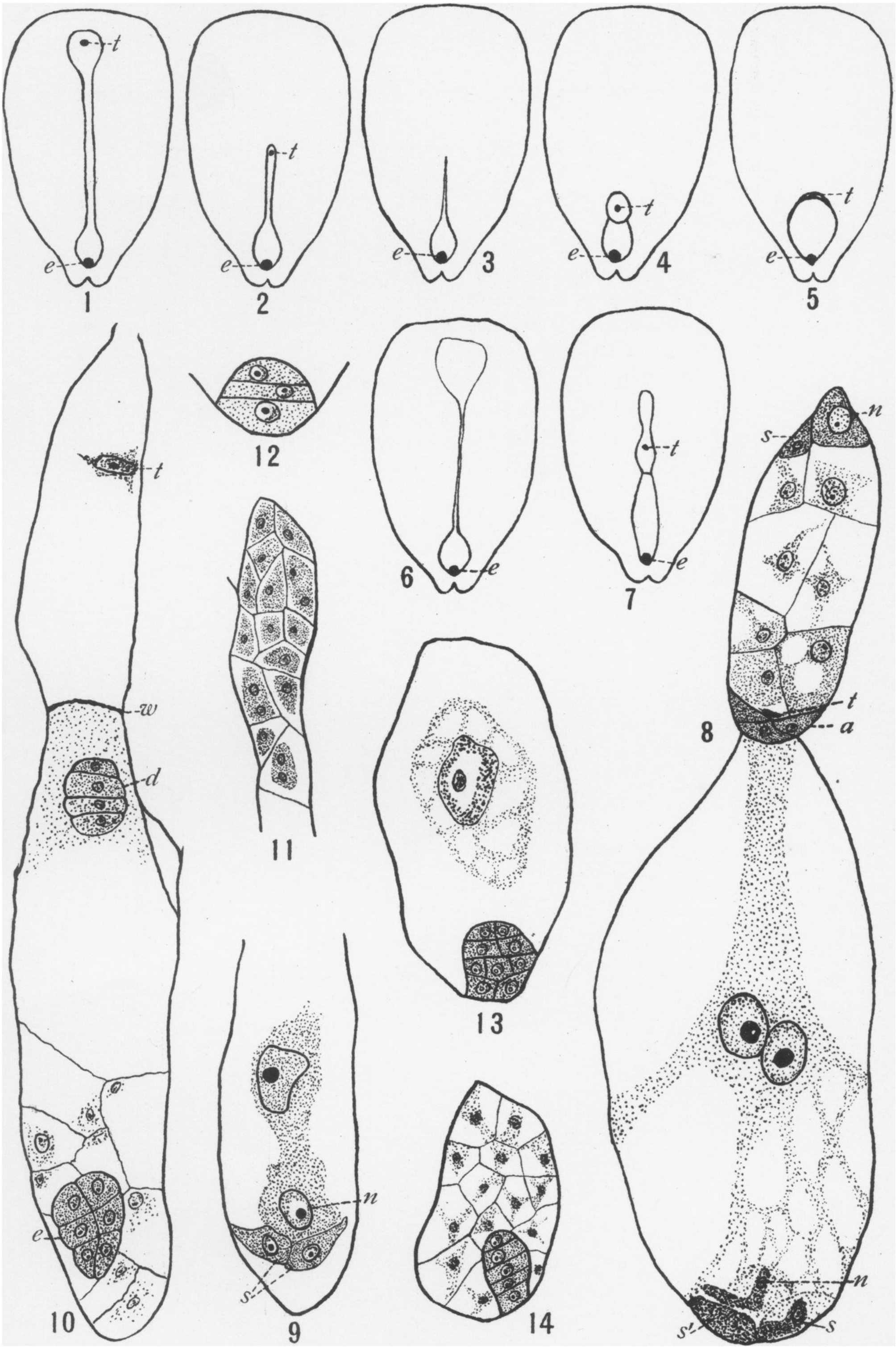
FIG. 10.—Embryo sac of *Nelumbo lutea*, showing embryo, cross-wall, and disentegrating tube nucleus.

FIG. 11.—Cells from the axial region of the ovule which may be the endosperm of unfertilized embryo sacs; from same section as *fig. 10.*

FIG. 12.—Embryo of *Nymphaea advena.*

FIG. 13.—Embryo of *Castalia odorata* and sac with the undivided endosperm nucleus; embryo without suspensor.

FIG. 14.--Embryo of *Castalia odorata* with suspensor.



COOK on NYMPHAEACEAE